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NIMBUS IV IRIS SPECTRA IN THE 750-1250 cm^{-1} ATMOSPHERIC WINDOW REGION

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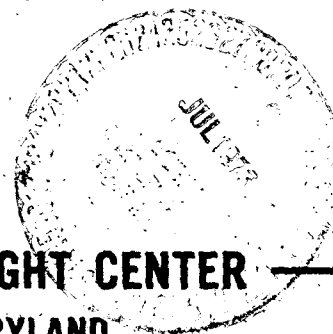
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MAY 1973



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ABSTRACT

Several Nimbus IV IRIS spectra are presented for the 700-1300 cm^{-1} region as examples of free atmosphere spectra to illustrate problems encountered in interpreting window measurements. Several atmospheric windows near 936 and 960 cm^{-1} appear significantly more transparent than the 899 cm^{-1} window presently used in operational remote sensing systems.

NIMBUS IV IRIS SPECTRA IN THE 750-1250 cm^{-1}

ATMOSPHERIC WINDOW REGION

1. INTRODUCTION

Considerable research is currently concerned with improving the accuracy of surface temperature estimates from infrared remote sounding measurements (Smith, 1969; Smith, et al., 1970; Anding and Kauth, 1970; Braun, 1971; Shenk and Salomonson, 1972; Prabhakara, et al., 1973; Maul and Sidran, 1973; Price, 1973). Following the investigations of Saiedy and Hilleary (1967), present operational schemes for determining the surface temperature rely on a radiometric measurement at 899 cm^{-1} . Even though this is one of the more transparent portions of the 750-1250 cm^{-1} window, it is still necessary to account for atmospheric absorption by applying an estimated correction. One of the future methods for obtaining surface temperature from remote sensing may involve multi-channel measurements which in principle will allow more realistic atmospheric corrections and will also cope with the partial cloud cover problem. In the simplest case, for clear atmospheres, only two channels with the emergent radiances linearly related are needed for the retrieval of the surface temperature.

In this note several Nimbus IV IRIS spectra in the 750-1250 cm^{-1} region are presented as examples of remotely-sensed spectra for investigating the optimum spectral intervals for determination of the surface temperature. Several windows have been found to be more transparent than the 899 cm^{-1} channel.

2. DESCRIPTION OF OBSERVED SPECTRA

The Nimbus IV infrared interferometer spectrometer (IRIS) measured the thermal emission of the Earth's atmosphere and surface in the $400\text{--}1600\text{ cm}^{-1}$ region with an apodized spectral resolution of 2.8 cm^{-1} (Hanel, et al., 1972). The brightness temperature ratio $T_{bb(\nu)} / \bar{T}_{bb}(899\text{ cm}^{-1})$ has been computed in the $700\text{--}1300\text{ cm}^{-1}$ region for several spectra representing different climatological conditions (see Figures 1 and 2). The quantity $\bar{T}_{bb}(899\text{ cm}^{-1})$ is the brightness temperature obtained by averaging the IRIS spectrum over the spectral response of the Nimbus 4 SIRS 899 cm^{-1} channel. The SIRS response is trapezoidal in shape, with the top width 2.4 cm^{-1} and the base width 13 cm^{-1} (The Nimbus IV Users Guide, 1970) and was chosen as typical of an operational type channel. Values of the brightness temperature ratio exceeding unity represent more transparent windows than the 899 cm^{-1} channel. The three spectra illustrated include a tropical ocean case near Guam (4/27/70) and a mid-latitude ocean case near Wallops Island (6/25/70), as shown in Figure 1, and a desert case over the Sahara (5/5/70) shown in Figure 2. The total H_2O content in each atmosphere is indicated in the figures. Corresponding to the minimum in the water vapor continuum (Bignell, 1970), the maximum observed brightness temperatures occur in the $1100\text{--}1200\text{ cm}^{-1}$ region.

The strong appearance of the H_2O lines in the desert spectrum is mainly a surface-atmosphere contrast effect rather than a large amount of H_2O , which is estimated to be 2.4 precipitable cm. The lower brightness temperatures on the

high wave number side of the 1042 cm^{-1} O_3 band with respect to the lower wave number side results from SiO_2 reststrahlen in the desert surface (Hanel, et al., 1972). This particular desert spectrum exhibits a weak reststrahlen effect of only several degrees. The desert spectrum will not be considered further.

Comparisons of synthetic IRIS radiances, computed with the Bignell (1970) water vapor continuum, with observed radiances give good relative and absolute agreement in the $700\text{--}1300\text{ cm}^{-1}$ region (Kunde, et al., 1973). As the water vapor continuum is well established (Bignell, 1970; Burch, 1970), the good agreement substantiates the calibration of the instrument. The accuracy of the calibration is further substantiated by the close agreement with Nimbus IV SIRS measurements in this spectral region.

3. MULTI-CHANNEL WINDOW REGIONS

The Guam brightness temperature ratio has been degraded to 10 and 50 cm^{-1} resolution, shown in the lower portion of Figure 3, with the lower spectral resolution being representative of the resolution anticipated in the multi-channel concept. At the 50 cm^{-1} resolution, individual H_2O absorption lines are almost completely degraded into a continuum. The brightness temperature ratio averaged over 50 cm^{-1} gives some guidance for proper selection of channels for the multi-channel concept for retrieval of surface temperature. The $825\text{--}950\text{ cm}^{-1}$ and $1110\text{--}1200\text{ cm}^{-1}$ regions should be satisfactory in avoiding the influence of the strong atmospheric absorption regions and retaining as much as possible an approximately linear relationship between channels.

4. NARROW WINDOW REGIONS

The spectra exhibit a number of narrow window regions containing only very weak atmospheric lines and exhibiting a minimum of selective absorption. The difference between the measured and surface temperature has been computed for several of these windows for the Guam and Wallops Island cases and additionally for another Wallops Island case obtained on June 8, 1970, and discussed previously (Kunde, et al., 1973). All three cases represent clear atmospheres. The differences were formed from the observed spectra degraded with a triangular filter function of 10 cm^{-1} total width at half-maximum, as in Figure 3 for Guam. This allows the comparison of the different windows at a spectral resolution approximating the present 899 cm^{-1} channel of operational systems. The temperature differences are summarized in Figure 4 for windows at 899, 936, 960, 1095, 1126, 1160, and 1202 cm^{-1} . The IRIS noise equivalent temperature (NET) of 0.3 degree is also indicated in the figure.

The physical mechanisms which may interfere with surface temperature retrievals and their dominant region of interference are sketched near the top of the figure. In the $1000\text{--}1200\text{ cm}^{-1}$ region atmospheric aerosols may reduce the observed brightness temperatures up to several degrees (Curran and Conrath, 1972). Surface reststrahlen effects in this region may be considerably larger, up to twenty degrees (Hanel, et al., 1972). Atmospheric water and ice clouds may depress the spectrum from 5-10 degrees at 800 cm^{-1} to several degrees in the $950\text{--}1000\text{ cm}^{-1}$ region (Hanel, et al., 1972; Curran, 1972).

The clearest windows are at 936 and 960 cm^{-1} with these two windows experiencing ~ 0.5 – 0.7 degree less absorption than the 899 cm^{-1} window. Using a high spectral resolution solar spectrum Saiedy and Hilleary (1967) originally chose the 899 cm^{-1} window as the clearest 5–8 cm^{-1} interval near the minimum of the water vapor continuum absorption curve. The 936 and 960 cm^{-1} windows were apparently avoided due to the lines of the 961 cm^{-1} CO_2 band in these regions. However, as is evident in the IRIS spectra the small amount of CO_2 absorption is more than compensated by the decreasing water vapor continuum absorption. The correction for the CO_2 contribution to the absorption would be essentially constant. The two windows at 1095 and 1126 cm^{-1} are also slightly better than the 899 cm^{-1} channel at the 10 cm^{-1} resolution.

At higher spectral resolution selective absorption effects can be more easily minimized and the windows in the 1090–1210 cm^{-1} range become the most transparent. Increasing water vapor amounts favor these windows near the minimum of the continuum absorption as the continuum absorption increases at a faster rate than the selective absorption. The disadvantages of using the 1090–1210 cm^{-1} region are 1) atmospheric aerosol and surface reststrahlen effects and 2) a lower signal to noise ratio resulting from both the higher spectral resolution required and the lower Planckian intensity.

5. CONCLUSIONS

The IRIS spectra indicate several narrow atmospheric windows in the 700–1300 cm^{-1} region which are more transparent than the 899 cm^{-1} channel currently

used operationally. At 10 cm^{-1} spectral resolution the windows at 936 and 960 cm^{-1} experience $1/2^\circ\text{K}$ less atmospheric absorption than the 899 cm^{-1} window and also are less affected by atmospheric water and ice clouds. The approximate linear regions of the spectrum for multi-channel retrieval of surface temperature are $825\text{--}950\text{ cm}^{-1}$ and $1110\text{--}1200\text{ cm}^{-1}$.

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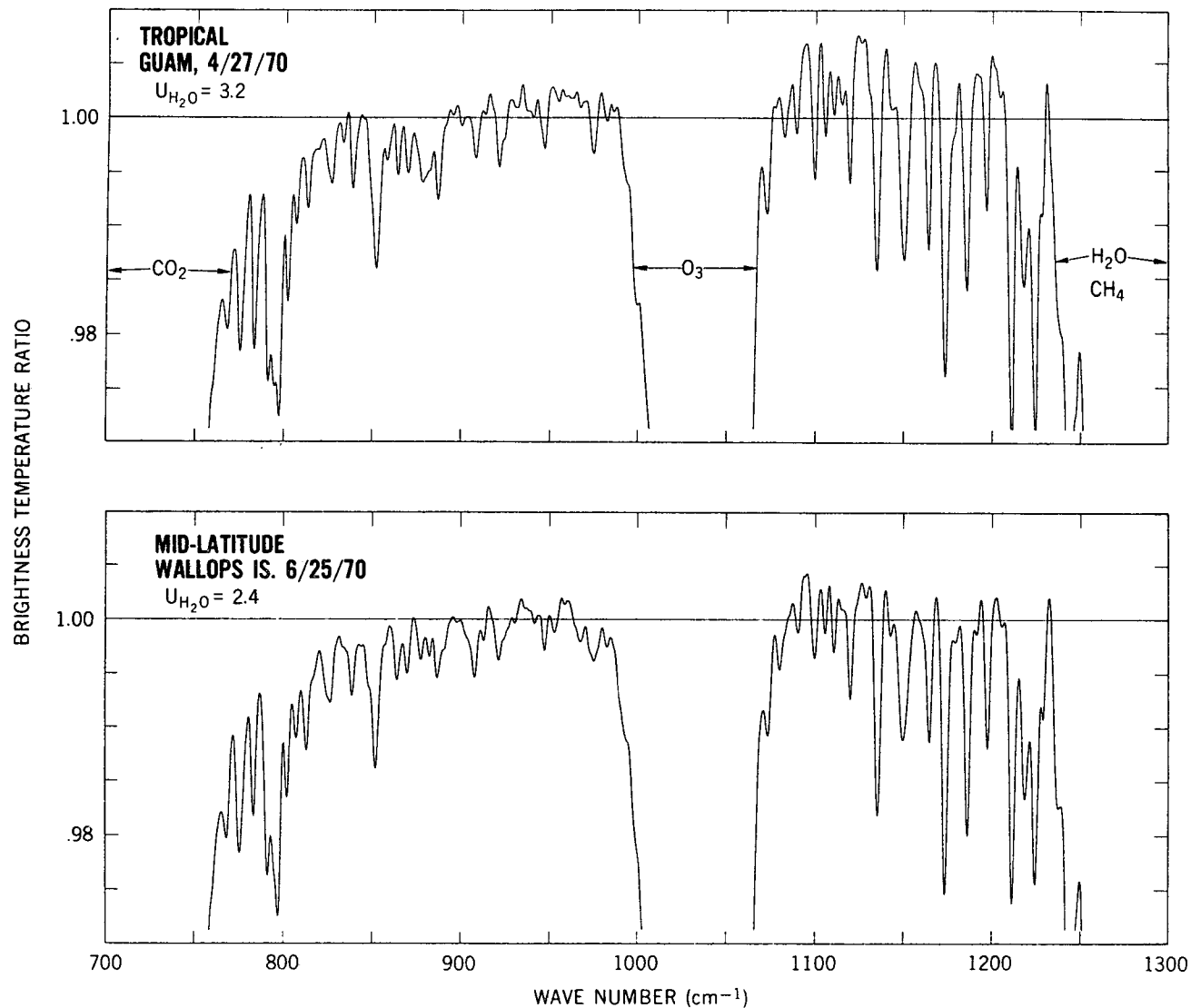


Figure 1 - The observed 700-1300 cm^{-1} atmospheric window spectrum is shown in terms of a brightness temperature ratio for the Guam and Wallops Island cases at 2.8 cm^{-1} resolution. Values of the ratio exceeding unity represent windows clearer than the present operational window channel at 899 cm^{-1} .

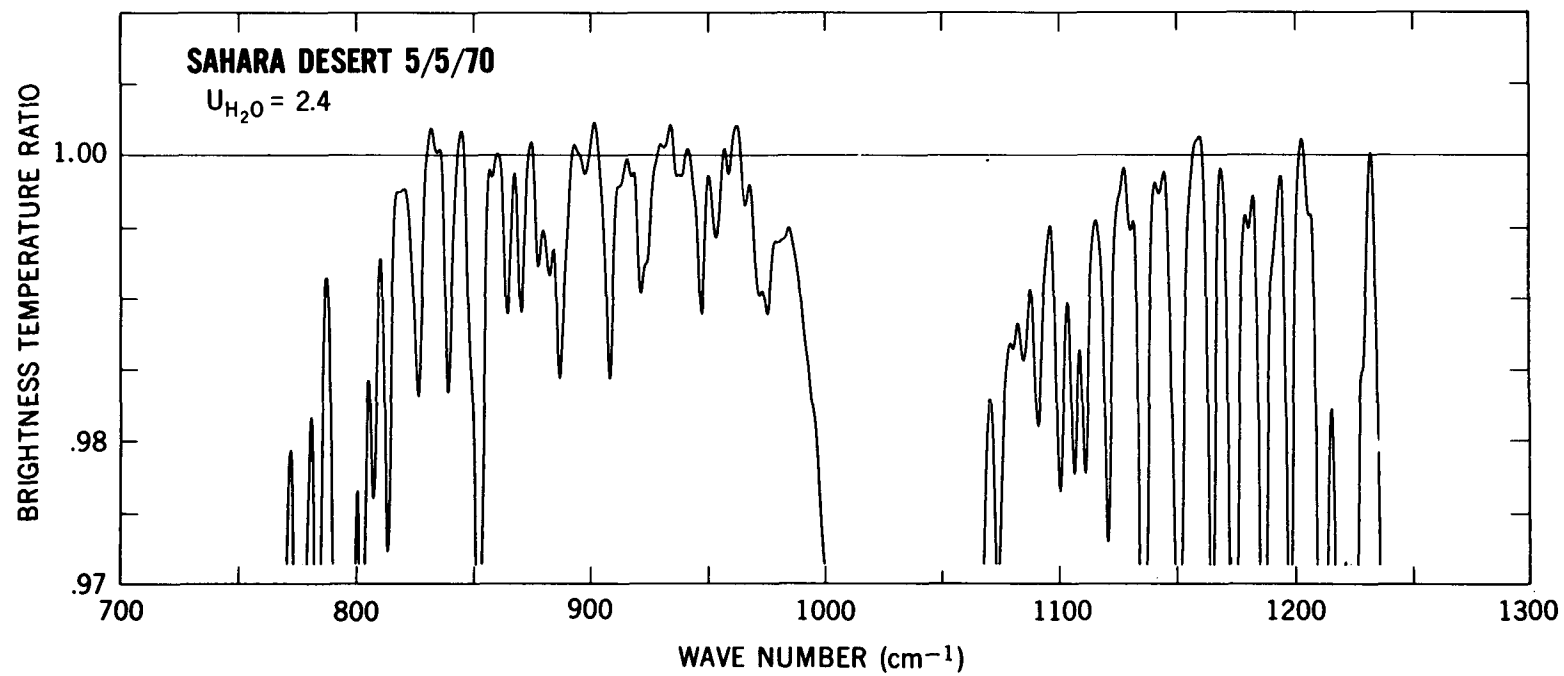


Figure 2 - Same as Figure 1, for Sahara desert spectrum.

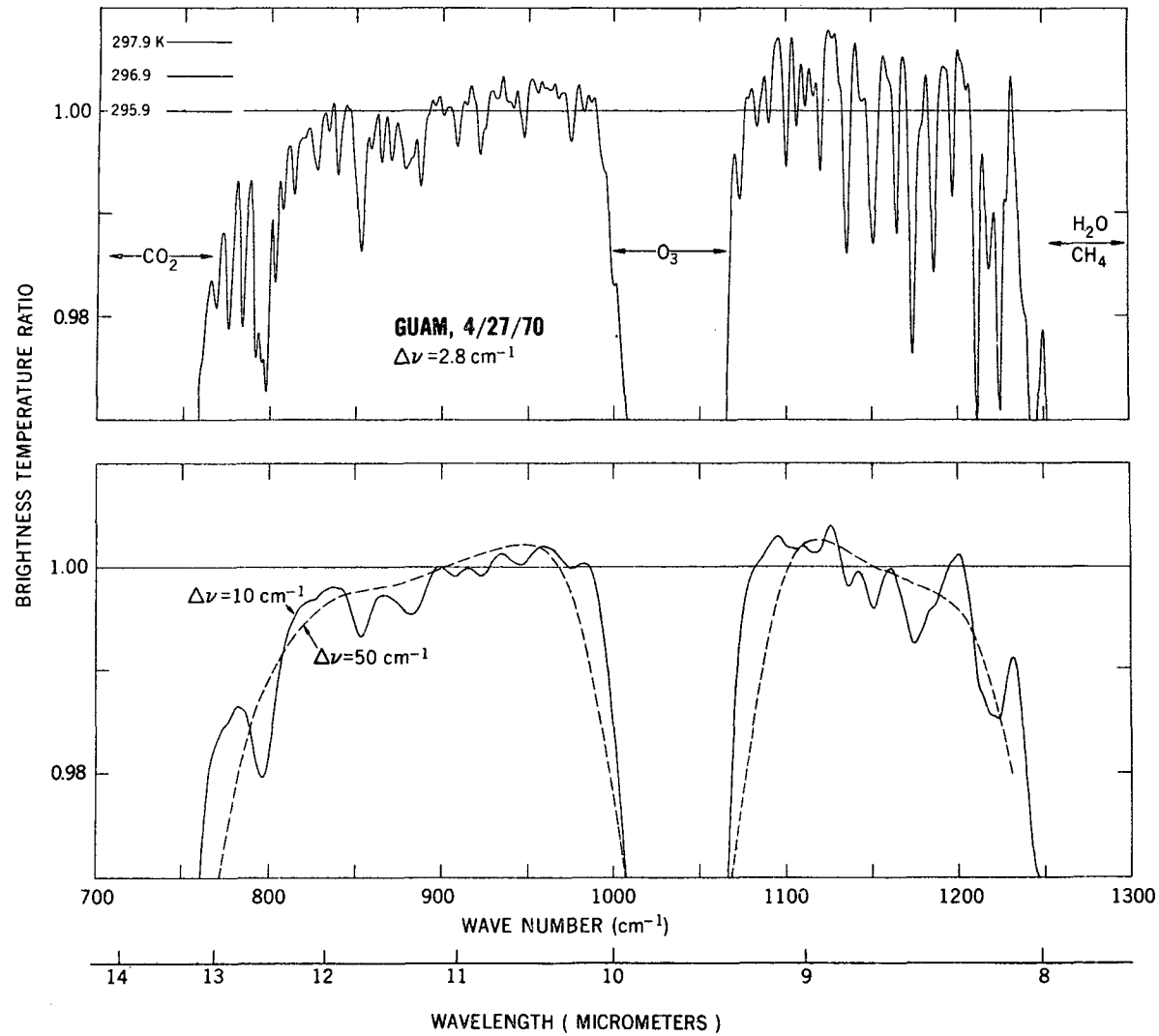


Figure 3 - Guam ratio spectrum at IRIS resolution (2.8 cm^{-1}) and degraded with a triangular filter function to 10 and 50 cm^{-1} resolution.

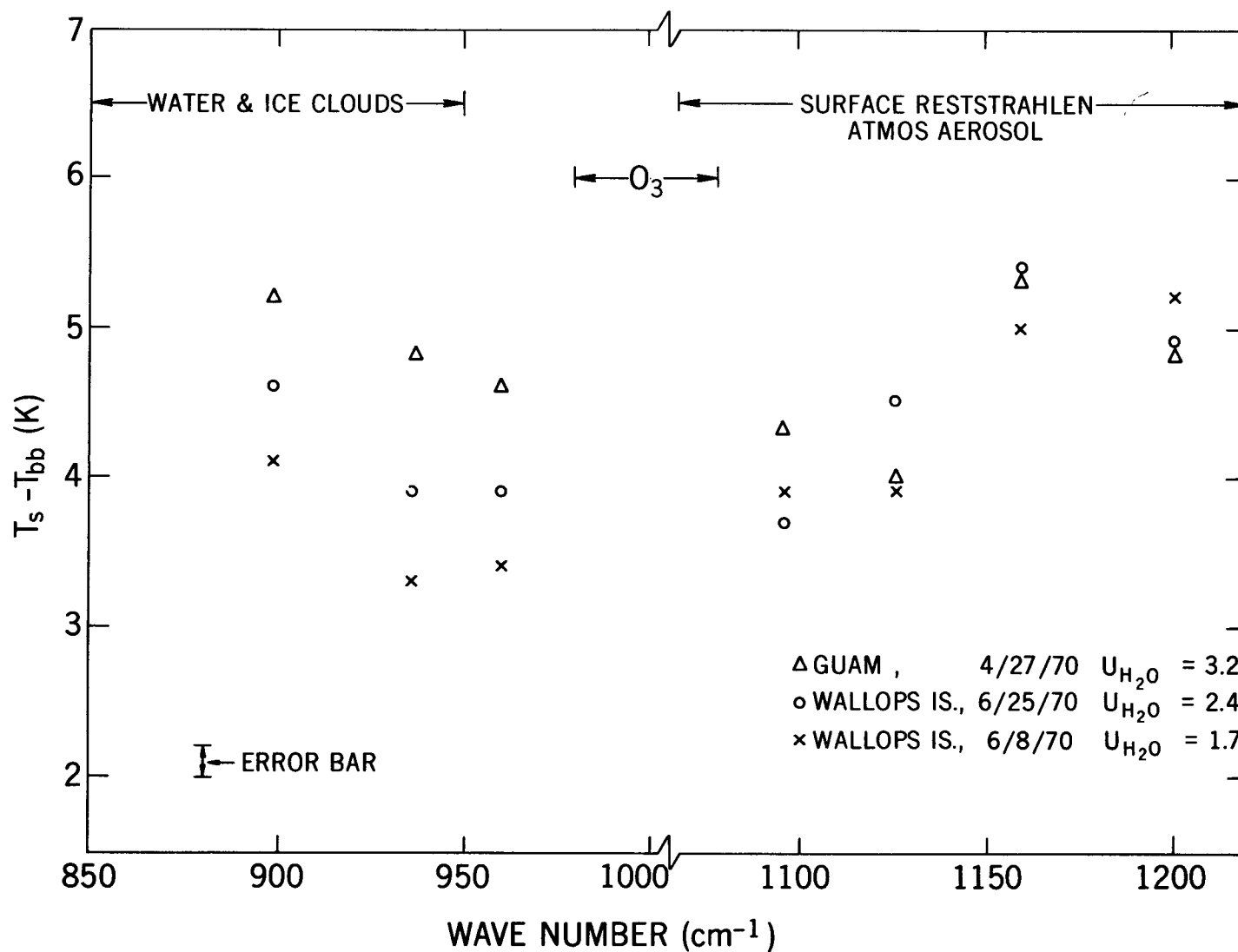


Figure 4 - Temperature difference between surface temperature and observed brightness temperature at 10 cm⁻¹ resolution for selected narrow windows in 700-1300 cm⁻¹ region. For these clear atmosphere cases, the clearest windows are at 936 cm⁻¹ and 960 cm⁻¹.